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STMICROELECTRONICS, INC.
MAIL STATION 2346
1310 ELECTRONICS DRIVE
CARROLLTON, TX 75006

EXAMINER	
TUCKER, WESLEY J	
ART UNIT	**PAPER NUMBER**
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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	09/927,558	CHEN, GEORGE Q.	
	Examiner	Art Unit	
	Wes Tucker	2624	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *19 July 2006*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-29* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-29* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *10 August 2001* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

Response to Amendment

1. Applicant's amendment filed July 19th 2006 has been entered and made of record.

2. The Advisory Action filed September 19th 2006 is hereby withdrawn. The Finality of the previous Final Office Action filed April 19th 2006 was not indicated in the Office Action, therefore the case appeared in Examiner's after-final docket in error. Therefore the Applicant's amendments in the response filed September 28th 2006 are hereby addressed in this Office Action.

3. Applicant has amended claims 1, 12, 18 and 29. Claims 1-29 remain pending.

4. Applicant's arguments are unpersuasive as the cited references are still deemed to read on the claimed invention.

With regard to claims 1, 12 and 18, the added claim language of at least three <u>relative views</u> of a scene wherein <u>three or more images are captured relative to each other and are of the same scene</u> does not further limit the claims in view of the presented prior art. Clearly the reference to Chen discloses this. The views are all of the same object and the views are "relative" to each other. What views of the same object would not be "relative"? In the remarks Applicant explains relative views as "each of the three view is relative to one another, e.g. they all include at least an

overlapping portion of the scene relative to each other." Clearly the reference to Chen discloses this.

With regard to claim 1, With regard to independent claim 29, Applicant has amended the claim to overcome the applied 101 rejection. Applicant has added the features of "capturing a base image representing a view of the scene; and tracing at least one parameter surface associated with the base image, each of the at least one prameter surface traced starting fro at least one predetermined seed pixel point associated with the base image; and [lots of equations and variables]; and storing the caculated derivative E(g) ina memory." This is still not considered to produce a useful, concrete and tangible result. The preamble states that the method is for recovering depth information and the calculated derivative equation E(g) is a function of the depth parameter. However, the final result of the claim is stoing a calculated derivative of the function E(g) in a memory and while that derivative may be useful to the computer, sinply storing the result of a calculation is not tangible or concrete or useful until it is applied to something in the real world, like the image itself or until the result is used to produce something else. As the claim is now worded it is still unclear what the purpose for the calculated derivative is. Therefore the 101 rejection still applies to claim 29 in its current form.

Claim Rejections - 35 USC § 101

5. Claim 29 is rejected under 35 U.S.C. 101 because the claimed invention is directed to non-statutory subject matter. Claim 29 is drawn to a computer-implemented

process that merely manipulates data or an abstract idea, or merely solves mathematical problem without a limitation to a practical application in the technological arts. Namely, claim 29 discusses recovering depth information in the preamble of the claim as the main purpose of the method, but does specifically connect depth information to a tangible or concrete result. Claim 29 appears to only disclose a manipulation or calculation of data with no intent of purpose or way of using the result of such calculation.

In order for a claimed invention to accomplish a practical application, it must produce a "useful, concrete and tangible result" State Street, 148 F.3d at 1373, 47 USPQ2d at 1601-02 (see MPEP 2106.II.A). a practical application can be achieved through recitation of "a physical transformation outside the computer for which a practical application in the technological arts is either disclosed in the specification within the technological arts is either disclosed in the specification or would have been known to a skilled artisan", or "limited to a practical application within the technological arts" (MPEP 2106 IVB2(b)). Currently, claim meets neither of these criteria. In order for the claimed process to produce a "useful, concrete and tangible" result, recitation of one or more of the following elements is suggested:

- The manipulation of data that represents a physical object or activity transformed from outside the computer (MPEP 2106 IVB2(b)(i)).
- A recitation of a physical transformations outside the computer, for example in the form of pre or post computer processing activity (MPEP 2106 IVB2(b)(i).

- A direct recitation of a practical application in the technological arts (MPEP 2106 IVB2(b)(ii)).

Appropriate correction is required.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 1, 4-9, 12-18 and 21-28 are rejected under 35 U.S.C. 103(a) as being unpatentable over the combination of the publication by [Chen, VSMM99] (Chen and Medioni , "A Volumetric Stereo Matching Method: Application to Image-Based Modeling", IEEE 1999) and U.S. Patent 5,853,672 to Lu.

With regard to claim 1, [Chen, VSMM99] describes a volumetric stereo matching method. The method involves the recovery of depth information – namely, the disparity surface *d(u,v)* (see [Chen, VSMM99]: Abstract, sentence 1; page 29, right column, last paragraph[1], sentences 1-3; and page 30, left column, paragraph 1, sentences 2-3) – for

[1] When referring to paragraphs in the cited references, the convention followed here is that the paragraph number is assigned to paragraphs of a given column (if applicable) or section, sequentially, beginning with the first full paragraph. Paragraphs that carry over to other columns will be referred to as the last paragraph of the column in which they began.

pixels of a base image representing a view of a scene. The method comprises at least the following steps:

(1.a.) Detecting a plurality of pixels in a base image that represents a first view of a scene wherein the first view is one of at least three views of a scene (e.g. capturing images from various viewpoints of the scene). It should be apparent from the various stereo images shown in [Chen, VSMM99] that the volumetric stereo matching method involves this step. Any one of these images can be arbitrarily denoted as a "base image". *See Also Example 4 on page 34, where 6 views of a teapot are used.*

(1.b.) Determining 3-D depth of the plurality of pixels in the base image by matching correspondence to a plurality of pixels in <u>three or more images</u> each image representing one of the at least three views of the scene wherein each of the at least three views of the scene are situated in a non-linear arrangement and are further oriented in a plurality of non-parallel planes relative to each other. See Also Example 4 on page 34, where 6 views of a teapot are used. Chen discloses using views of a teapot as it is rotated, the views of which would therefore not lie on parallel planes.

Steps (1.a.)-(1.b) are typical of any stereo matching applications. The "matching correspondence" is discussed in Section 3.1 of [Chen, VSMM99]. The cross-correlation

□*u,v,d*is indicative of the matching correspondence between pixels of different images, each of which are representative of disparate views of the scene.

(1.c.) Tracing pixels (i.e. *surface tracing*) in a virtual piecewise continuous depth surface (i.e. *disparity surface* $d(u.v)$) by spatial propagation ([Chen, VSMM99] section 3.2, paragraph 1, sentence 4) starting from the detected pixels in the base image (i.e. all pixels (u,v) of the base image) by using the matching and corresponding plurality of pixels in the <u>three or more</u> images (e.g. *seed pixels* that satisfy a given cross-correlation criterion – [Chen, VSMM99] page 31, right column, paragraph 1, sentences 1-2) to create the virtual piecewise continuous depth surface viewed from the base image. Please refer to Section 3 of [Chen, VSMM99].

(1.d.) Each successfully traced pixel is associated with a depth in the scene viewed from the base image. This follows from the fact that traced pixels lie on the disparity surface. Again, the disparity surface is indicative of the depth of all visible surfaces of a given scene (page 29, right column, last paragraph, sentences 1-3).

In this manner, the a volumetric stereo matching method of [Chen, VSMM99] conforms sufficiently to the method proposed by the Applicant in claim 1.

Applicant has amended the independent claims 1, 12 and 18 to include the limitation of <u>**wherein the three or more images are captured simultaneously.**</u>

[Chen, VSMM99] does not explicitly disclose wherein the three images are captured simultaneously.

Lu teaches the simultaneous capture of multiple images (column 3, lines 56-64 and column 6, lines 1-10 and Fig.) for use in an embodiment similar to that of [Chen VSMM99]. In the invention of Lu, the advantage of capturing the images at a single moment in time is advantageous in order to ensure that objects being captured do not move or shift between image capture from different images. Therefore it would have been obvious to one of ordinary skill in the art at the time of invention to capture multiple images simultaneously for generating 3D image data from matching the different images in order to ensure that the images represent the objects in the same position so that all of the images to be matched represent the same set of data defining the object in combination with the 3D depth recovery information disclosed by [Chen VSMM99].

The following is in regard to Claim 18. Claim 18 recites essentially the same limitations as claim 1. (The 3D reconstruction instructions merely implement the depth recovery method of Claim 1). Therefore, with regard to claim 18, remarks analogous to those presented above relative to claim 1 are applicable.

The following is in regard to Claim 4. As shown above, the combination of [Chen, VSMM99] and Lu discloses a volumetric stereo matching method that adequately conforms to the depth recovery method of Claim 1. The volumetric stereo matching method of [Chen, VSMM99] further involves:

Propagating a front of a virtual piece of a continuous depth surface (e.g. a *surface front* – this terminology is used in sentence 5 of the last paragraph of the right column on page 31) to at least one neighboring pixel (e.g. each *4-neighbor* of (u,v) – Fig. 4 of [Chen, VSMM99]) starting from the detected pixels (e.g. pixel (u,v)) in the base image.

It should be apparent from the algorithm listed in Fig. 4 of [Chen, VSMM99] that the boundary (front) of the disparity surface is propagated. In this manner, the volumetric stereo matching method of [Chen, VSMM99] conforms sufficiently to the method proposed by the Applicant in Claim 4.

The following is in regard to Claim 21. Claim 21 recites essentially the same limitations as claim 4. (The 3D reconstruction instructions merely implement the depth recovery method of Claim 4). Therefore, with regard to claim 21, remarks analogous to those presented above relative to claim 4 are applicable.

The following is in regard to Claims 5-6. As shown above, the combination of [Chen, VSMM99] and Lu discloses a volumetric stereo matching method that adequately conforms to the depth recovery method of Claim 4. Tracing the disparity surface according to the volumetric stereo matching method of [Chen, VSMM99] further involves the following:

(5.a.) Determining when a boundary is reached between two propagating fronts of virtual pieces of a continuous depth surface ([Chen,

VSMM99] page 31, right column, last paragraph, sentence 5).

If the boundaries of two propagating fronts coincide then:

(6.a.) Comparing the cross-correlations of the two propagating fronts about the reached boundary. This comparison is performed, for example, in the following step shown in [Chen, VSMM99] Fig. 4:

disparity(u',v') = □u',v',d'□□ u',v',d''□d' □d''

Clearly, a comparison of the cross-correlations, □$u',v',d'$and□ u',v',d'' is tantamount to a comparison of the matching costs of the two surface fronts

(6.b.) The surface front with the greatest cross-correlation prevails ([Chen, VSMM99] page 31, right column, last paragraph, sentence 5). In other words, the propagation of the front with the lower cross-correlation is stopped.

Step (6.b.) is equivalent to stopping the propagation of the front with the higher compared matching cost[2]. In this manner, the a volumetric stereo matching method of [Chen, VSMM99] conforms sufficiently to both the methods of Claim 5 and the method of Claim 6.

The following is in regard to Claim 22-23. Claims 22-23 recite essentially the same limitations as claim 5-6, respectively. (The 3D reconstruction instructions of these

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[2] To see this recall how the Applicant defines matching cost (page 9, lines 10-15 of the Applicant's disclosure and, in particular, equation (8) on page 17). The matching cost is low for pixels that are likely matches and is high for unlikely matches. The relationship between the matching cost and cross-correlation (NCC) is shown in the Applicant's equation (8). Clearly, a high NCC results in a low matching cost $E(g)$ and indicates a likely match, whereas a low NCC results in a high matching cost and indicates an unlikely match. Therefore, by stopping the propagation of the front with the lower NCC, one has effectively stopped the propagation of the front with the higher matching cost.

claims merely implement the depth recovery methods of Claim 5-6). Therefore, with regard to claim 22-23, remarks analogous to those presented above relative to claim 5-6 are respectively applicable.

The following is in regard to Claim 7. As shown above, the combination of [Chen, VSMM99] and Lu discloses a volumetric stereo matching method that adequately conforms to the depth recovery method of Claim 1. Tracing the disparity surface according to the volumetric stereo matching method of [Chen, VSMM99] further involves the following:

> Propagating a front of a virtual piece of a continuous depth surface to at least one neighboring pixel surrounded by a predefined size window in the continuous depth surface. According to the volumetric stereo matching method of [Chen, VSMM99], the normalized cross-correlation (NCC) over a window (e.g. one with dimensions and centered at pixels (u,v) and $(u+d,v)$) is used as the similarity measurement. See Section 3.1 of [Chen, VSMM99].

In this manner, the a volumetric stereo matching method of [Chen, VSMM99] conforms sufficiently to the method of Claim 7.

The following is in regard to Claim 24. Claim 24 recites essentially the same limitations as claim 7. (The 3D reconstruction instructions merely implement the depth recovery method of Claim 7). Therefore, with regard to claim 24, remarks analogous to those presented above relative to claim 7 are applicable.

The following is in regard to Claim 8-9 and 25-26. As shown above, the combination of [Chen, VSMM99] and Lu discloses a volumetric stereo matching method that adequately satisfies the limitations of Claims 7 and 24. The limitations set forth in Claims 8-9 and 25-26 were addressed previously in the discussion above relating to Claims 5-6 and 22-23. The details will not be repeated here.

The following is in regard to Claim 12. [Chen, VSMM99] discloses a volumetric stereo matching method that includes the following:

(12.a.) Providing a plurality of seed pixels that represent 3-D depth of the plurality of pixels in the base image view of a scene (i.e. *seed voxels* – [Chen, VSMM99] page 31, right column, paragraph 1). Seed voxels are determined by matching correspondence to a plurality of pixels in <u>three or more</u> images representing a plurality of views of the scene, wherein the base image is one of at least three views of the scene, each of the at least three views of the scene being situated in a non-linear arrangement and are further oriented in a plurality of non-parallel planes relative to each other (i.e. ensuring that the cross-correlation □*u,v,d* between the views satisfies □*u,v,d*□*t1*, *t1* being a predetermined threshold – [Chen, VSMM99] page 31, right column, paragraph 1, lines 3-4). See also example 4 on page 34 with the 6 rotating views of the teapot.

(12.b.) Tracing pixels in a virtual piecewise continuous depth surface by spatial propagation starting from the provided plurality of seed pixels in the base image by using the matching and corresponding plurality of pixels in the <u>three or more</u> images to create the virtual piecewise continuous depth surface viewed from the base image, each successfully traced pixel being associated with a depth in the scene viewed from the base image. The surface tracing was treated above with respect to step (1.c.). See also [Chen, VSMM99] right column, paragraph 2 and Fig. 4.

[Chen, VSMM99] presents the volumetric stereo matching method entirely as an algorithm and forgoes any mention of possible hardware implementations. However, the volumetric stereo matching method is shown to have been executed on a computer (e.g. SGI workstation – [Chen, VSMM99] page 34, left column, paragraph 2). In this case, item (12.a.) would be implemented in computer-readable instructions, say as a "image matching module", and item (12.b.) would be implemented in computer-readable instructions, say as a "propagation module". The "image matching module" and "propagation module" would presumably be resident (electrically coupled) in some memory which is, in turn, coupled to a central processing unit (CPU). In this manner, a computer implementation of the a volumetric stereo matching method of [Chen, VSMM99] would sufficiently conform to the image processing system of Claim 12.

Applicant has amended the independent claims 1, 12 and 18 to include the limitation of **wherein the three or more images are captured simultaneously.**

[Chen, VSMM99] does not explicitly disclose wherein the three images are captured simultaneously.

Lu teaches the simultaneous capture of multiple images (column 3, lines 56-64 and column 6, lines 1-10 and Fig.) for use in an embodiment similar to that of [Chen VSMM99]. In the invention of Lu, the advantage of capturing the images at a single moment in time is advantageous in order to ensure that objects being captured do not move or shift between image capture from different images. Therefore it would have been obvious to one of ordinary skill in the art at the time of invention to capture multiple images simultaneously for generating 3D image data from matching the different images in order to ensure that the images represent the objects in the same position so that all of the images to be matched represent the same set of data defining the object in combination with the 3D depth recovery information disclosed by [Chen VSMM99].

The following is in regard to Claim 13. As shown above, the combination of [Chen, VSMM99] and Lu suggests a computer implementation of a volumetric stereo matching method that adequately satisfies the limitations of Claims 12. The disclosed volumetric stereo matching method operates on photographic images (e.g. [Chen, VSMM99] Figs. 2 or 8). This necessitates some means of capturing images, such as a camera(s) (see [Chen, VSMM99] page 34, left column, paragraph 1). In order for the CPU to process the captured images, the camera would have to be somehow

electrically coupled (e.g. via some camera interface) to the CPU. Therefore, the features of the image processing system proposed in Claim 13 are inherent to a computer-based implementation of the volumetric stereo matching method of [Chen, VSMM99].

The following is in regard to Claim 14. As shown above, the combination of [Chen, VSMM99] and Lu suggests a computer implementation of a volumetric stereo matching method that adequately satisfies the limitations of Claims 12. As mentioned above the "image matching module" and "propagation module" are resident on a memory. Modern memory is implemented as an integrated circuit. All modern CPUs are implemented as integrated circuits. In this manner, a computer-based implementation of the a volumetric stereo matching method of [Chen, VSMM99] would adequately satisfy the limitations of Claim 14.

The following is in regard to Claims 15-17. Claim 15-17 recite essentially the same limitations as claim 5-7, respectively. Therefore, with regard to claim 15-17, remarks analogous to those presented above relative to claim 5-7 are respectively applicable.

The following is in regard to Claim 27. As shown above, [Chen, VSMM99] discloses a volumetric stereo matching method that adequately satisfies the limitations of Claims 24. Although [Chen, VSMM99] does not explicitly mention associating the normalized cross-correlation (NCC) with a matching cost, the usage of the NCC in

[Chen, VSMM99] suggests that the two are closely related and could indeed be used interchangeably. As mentioned above, [Chen, VSMM99] uses the NCC, □*u,v,d* within windows associated with each of the propagating fronts (e.g. windows centered about the voxel (*u,v,d*) on the surface fronts – [Chen, VSMM99] page 31, left column, lines 1-3 and right column, paragraph 2, sentence 1) to determine which of two coincident surface fronts to continue to propagate ([Chen, VSMM99] page 31, right column, last paragraph, sentence 5). Furthermore, the NCC is indicative of the "correctness" of a match ([Chen, VSMM99], Section 3.2, paragraph 1, sentence 1). All of this is suggests the that the NCC provides an adequate measure of the matching cost of the propagating surface fronts. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to relate the matching cost of the propagating surface fronts to the computation of the NCC or designate the NCC as the matching cost. In either case, the motivation for doing so would have been to utilize the cross-correlative properties of the NCC to evaluate the degree to which voxels, comprising the surface fronts, represent correct matches.

The following is in regard to Claim 28. As shown above, [Chen, VSMM99] discloses a volumetric stereo matching method that, when modified in the manner suggested above, adequately satisfies the limitations of Claims 26. [Chen, VSMM99] suggests rectification of at least one pair of images corresponding to the base view of the scene and at least one of the other views (e.g. "reference views"). See [Chen, VSMM99] Section 2. Therefore, it would have been obvious to one of ordinary skill in

the art, at the time of the applicant's claimed invention, to further perform rectification of at least one pair of images corresponding to the base view of the scene and at least one of the other views (e.g. "reference views"). The result of rectification is that "scanlines [epipolar lines] are parallel in each image, and the corresponding ones are collinear across the images" ([Chen, VSMM99] Section 2, paragraph 1, sentence 2 and last paragraph). This is known to have the effect of greatly simplifying the problem of finding correspondences across stereo images.

7. Claims 2-3 and 19-20 are rejected under 35 U.S.C. 103(a) as being unpatentable over the combination of [Chen, VSMM99] and U.S. Patent 5,852,672 to Lu, in view of [Zhang94] (Zhang, Deriche, Faugeras, and Luong, "A Robust Technique for Matching Two Uncalibrated Images Through the Recovery of Unknown Epipolar Geometry", INRIA 1994).

The following is in regard to Claim 2. As shown above, the combination of [Chen, VSMM99] and Lu discloses a volumetric stereo matching method that sufficiently conforms to the depth recovery method proposed in Claim 1. The volumetric stereo matching method of [Chen, VSMM99] operates on multiple images (see, for instance [Chen, VSMM99] Fig. 2 and Fig. 11). That is, the depth recovery according to this method includes the following:

(2.a.) Detecting a plurality of image pixels in a first image corresponding to a first view of a scene.

(2.b.) Detecting a plurality of image pixels in at least a second image corresponding to a respective at least a second view of the scene. The at least a second image deviates from the first image as a result of camera relative motion. This is typical of stereo matching algorithms (see also [Chen, VSMM99] page 34, *Example 4*).

As noted above, the volumetric stereo matching method of [Chen, VSMM99], like most stereo matching methods, involves determining correspondences between a plurality of pixels in a first image and a plurality of pixels of at least a second image. In other words, the method of [Chen, VSMM99] further involves:

(2.c.) Determining a first two-view correspondence between the plurality of detected image pixels in the first image and a plurality of detected image pixels in one of the at least a second image resulting in a first potential match set of candidate image pixels between the first image and the one of the at least a second image. This process involves the evaluation of the cross-correlation □*u,v,d*as discussed above with regard to step (1.b.).

[Chen, VSMM99] further suggests subsequently computing the *projective reconstruction* from the derived correspondence information in order to reconstruct the projective 3D structure of the observed scene ([Chen, VSMM99] Section 4, paragraph 1).

[Chen, VSMM99] does not, however, expressly show or suggest:

(2.d.) Concatenating a plurality of two-view match sets to form a first

multiple-view potential match set; and

(2.e.) Determining a second multiple-view potential match set that is a refinement of the first multiple-view potential match set.

[Zhang94], on the other hand, discloses a stereo matching method. Stereo matching across disparate views of a scene is generally a fundamental step in depth recovery. The stereo matching method involves at least the following steps (refer to [Zhang94] Section 6.3 on pages 16-19):

(2.c.) Determining an initial set of correspondences or matches (e.g. a first two-view correspondence) between the plurality of detected image pixels in the first image and a plurality of detected image pixels in one of the at least a second image resulting in a first potential match set of candidate image pixels (e.g. *candidate matches* - see, for example, [Zhang94] page 10, Section 5, paragraph 1, lines 1-2) between the first image and the one of the at least a second image.

(2.d.) Removing outliers from the initial set of matches (i.e. determining a "multiple-view correspondence" between the plurality of detected image pixels in the first image and the plurality of detected image pixels in the at least a second image). See, for example, [Zhang94] page 18, line 24[3], in conjunction with the equations for the weights w_i on pages 17-18. In this manner, the set of matches or

[3] Lines are counted sequentially from the top beginning with 1. An equation is treated as a single line, regardless of its length.

correspondences thus obtained (e.g. the "multiple-view correspondences") represents a refinement of the "first two-view correspondence", resulting in a "second potential match set" of candidate image pixels between the first image and the at least a second image.

(2.e.) The "second potential match set" is based at least in part on a computation of reprojection error (e.g. *residual* r_i – [Zhang94] page 17, paragraphs 1-2) for matched pixels that resulted from "the difference between the *i*-th observation and its fitted value[4]" ([Zhang94] page 17, paragraph 1, lines 1-2).

The teachings of [Chen, VSMM99] and [Zhang94] are combinable because they are analogous art. Specifically, both [Chen, VSMM99] and [Zhang94] disclose methods for stereo matching. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use the methodology of [Zhang94] – in particular, steps (2.d.)-(2.e.) above – to refine the initial set of correspondences derived according to the method of [Chen, VSMM99]. It would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, that, in applying this refinement process to method of [Chen, VSMM99], the *fitted values* become the reprojected projective points that delimit the projective structure of the observed scene (i.e. "matched pixels that resulted from a projective reconstruction of

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4 It should be understood that the *fitted value* in this case is a projection of the matched pixels into some view being evaluated and the observation is the respective candidate point correspondences $\{(\mathbf{m}_{1i}, \mathbf{m}_{2i})\}$. See [Zhang94] page 17, last paragraph.

the first potential match set"). The motivation for using the method of [Zhang94], in this manner, would have been to detect and remove *outliers* (e.g. *bad locations* and/or *false matches* – [Zhang94] page 16, last paragraph) from the initial set of candidate matches (e.g. those obtained via step (2.c.) above). See [Zhang94] Section 6.3.

The following is in regard to Claims 19. Claim 19 recites essentially the same limitations as claim 2. (The 3D reconstruction instructions merely implement the depth recovery method of Claim 2). Therefore, with regard to claim 19, remarks analogous to those presented above relative to claim 2 are applicable.

The following is in regard to Claim 3. As shown above the methods of [Chen, VSMM99] and [Zhang94] can be combined to satisfy the limitations of Claim 2. [Zhang94] further disclose that the "outlier-less" set of correspondences (i.e. the "second potential match set") is based at least in part on a least median of squares computation (*LMedS* – [Zhang94] Abstract and page 17, lines 4-7 and paragraph 2) of the reprojection errors (i.e. *residuals* r_i – see above) related to matched pixels in the *first* potential match set. LMedS, as put forth by [Zhang94], has an advantage over other methods in that it "is very robust to false matches as well as outliers due to bad localization" ([Zhang94] page 17, paragraph 1, last sentence). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use the LMedS of [Zhang94] to detect and remove outliers from the first potential match set.

The following is in regard to Claim 20. Claim 20 recites essentially the same limitations as claim 3. (The 3D reconstruction instructions merely implement the depth recovery method of Claim 3). Therefore, with regard to claim 20, remarks analogous to those presented above relative to claim 3 are applicable.

8. Claims 10-11 and are rejected under 35 U.S.C. 103(a) as being unpatentable over the combination of [Chen, VSMM99] and U.S. Patent 5,852,672 to Lu, in view of [Okutomi93] (Okutomi and Kanade "A Multiple-Baseline Stereo", IEEE 1993), in further view of [Lewis95] (Lewis, "Fast Normalized Cross-Correlation", 1995).

The following is in regard to Claim 10. As shown above, [Chen, VSMM99] discloses a volumetric stereo matching method that sufficiently conforms to the depth recovery method proposed in Claim 9. As discussed above, the method of [Chen, VSMM99] involves the computation of the NCC between a first image window of a pre-determined size in the base view, and a second image window of the same pre-determined size in other views ([Chen, VSMM99] Section 3.1). It was also show above that the NCC is intimately related to the matching cost. Despite this, [Chen, VSMM99] does not expressly show or suggest that the matching cost is determined by computing the summation of all the normalized cross-correlations between a first image window of a pre-determined size in the base view, and a second image window of the same pre-determined size in a reference view.

[Okutomi93] disclose a stereo matching method that uses multiple stereo pairs with various baselines for the purposes of depth recovery ([Okutomi93] Abstract sentence 1). According to [Okutomi93], the summation of the sum of squared differences (SSD) from multiple stereo pairs can be used to indicate the "correctness" of a set of matching points (pixels). See [Okutomi93] page 353 (right column, paragraph 3, first and last sentence), page 354, (left column, lines 7-10), page 355 (Section B, paragraph 2, sentence 1), and equation (39) on page 362. This summation is analogous to a matching cost in that it approaches a minimum for correct matches ([Okutomi93] page 353, right column, paragraph 3, last sentence). According to equation (39) the computation is made within a predetermined window W belonging to each of the stereo images ([Okutomi93] page 354, right column, paragraph 1, line 4). In summary, [Okutomi93] shows a "matching cost" determined by computing the summation of all the *SSD's* between a first image window of a pre-determined size in the base view and a second image window of the same pre-determined size in other views (e.g. "reference views"). Given this, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use a "matching cost" (i.e. a measure of the similarity or "correctness" of a match) determined by computing the summation of all the *SSD's* between a first image window of a pre-determined size in the base view and a second image window of the same pre-determined size in other views (e.g. "reference views"). As pointed out by [Okutomi93], this would have the effect of advantageously reducing global mismatches ([Okutomi93], page 353, right column, paragraph 3, first sentence).

Note that the SSD and NCC are closely related mathematically. As measures of similarity among regions of images, they are functionally equivalent. See [Lewis95] Section 2, paragraph 1. Furthermore, it can also be shown that the process of minimizing the SSD and maximizing the NCC are in fact equivalent operations. All of this suggests that SSD and NCC are essentially interchangeable. Moreover, the NCC has the advantage over the SSD in that it is invariant to "changes in image amplitude such as those caused by changing lighting conditions across the image sequence" ([Lewis95] page 2, lines 8-17). Since lighting conditions are likely to vary across the various stereo images, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to substitute the NCC for the SSD in the stereo matching method of [Okutomi93]. This would yield a "matching cost" determined by computing the summation of all the *NCC's* between a first image window of a pre-determined size in the base view and a second image window of the same pre-determined size in other views (e.g. "reference views").

The teachings of [Chen, VSMM99] and [Okutomi93] are combinable because they are analogous art, namely, the art of stereo matching. The teachings of [Lewis95] are applicable to both the methods of [Chen, VSMM99] and [Okutomi93] because all relate generally to correlative approaches for evaluating the similarity of windowed-regions belonging to a collection of images of a scene. Combining these teachings as suggested above yields a method that conforms sufficiently to that of claim 10.

The following is in regard to Claim 11. As shown above the teachings of [Chen, VSMM99], [Okutomi93], and [Lewis95] can be combined so a to yield a method that adequately satisfies the limitations of Claim 10. [Chen, VSMM99] suggests rectification of at least one pair of images corresponding to the base view of the scene and at least one of the other views (e.g. "reference views"). See [Chen, VSMM99] Section 2. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to further perform rectification of at least one pair of images corresponding to the base view of the scene and at least one of the other views (e.g. "reference views"). The result of rectification is that "scanlines [epipolar lines] are parallel in each image, and the corresponding ones are collinear across the images" ([Chen, VSMM99] Section 2, paragraph 1, sentence 2 and last paragraph). This is known to have the effect of greatly simplifying the problem of finding correspondences across stereo images.

Conclusion

9. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Wes Tucker whose telephone number is 571-272-7427. The examiner can normally be reached on 9AM-5PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Matt Bella can be reached on 571-272-7778. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

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Wes Tucker

11-9-07

JINGGE WU
SUPERVISORY PATENT EXAMINER